Appendix C

Summary of Modeling Efforts Related to the Freeport Regional Water Authority Intake Project

MODELING APPROACH

Two models were used to study the impacts of the SRWTP discharge and the Freeport Regional Water Authority (FRWA) diversion on one another: the Fischer Delta Model (FDM) and the Longitudinal Dispersion (LD) model[1]. The FDM consists of two linked models, a hydrodynamic model and a water quality model. The hydrodynamic model utilizes the fixed grid method of characteristics solution of the St. Venant equations to simulate the hydrodynamics of the Delta. The water quality model uses the Lagrangian method in which the dilution of moving parcels of water is followed through the Delta. The FDM was used to simulate hourly flow rates in the Sacramento River at Freeport for a 73-year time period. Input to the FDM consisted of a 73-year simulated river hydrologic record representing a 2020 level of development applied to historical runoff (1922-1994). This record was generated by the East Bay Municipal Utility District (EBMUD) using the CALSIM II model, a model developed by the Department of Water Resources (DWR). Earlier evaluations were performed using a 70-year simulated hydrologic record generated by the PROSIM model, a model developed by the U.S. Bureau of Reclamation (USBR). The CALSIM II model has superseded the PROSIM model and is believed to simulate reservoir and water resources operations more accurately. Sacramento River flow simulation results from the FDM using the CALSIM II input data were evaluated to identify the time periods when three “worst-case” reverse flow events occurred. These three events (the largest reverse flow event, the longest reverse flow event, and an event with the largest “advective distance[2]”) occurred during two separate two-week periods in the water year 1977 (Period 1: May 25 – June 8, and Period 2: April 29 – May 12). These two time periods were then used in detailed evaluations of concentrations of treated effluent in the Sacramento River, particularly near the proposed FRWA diversion location.

Input to the LD model includes simulated flow rates of SRWTP treated effluent discharged to the river and adjusted Sacramento River flow rates that reflect the effect of FRWA diversions. The following parameters were also used in the analysis of interactions between the SRWTP and FRWA diversion: FRWA diversion pumping rates and the volume of water that could not be pumped by FRWA because of the potential presence of treated effluent at the FRWA diversion location (the volume of water that could not be pumped is referred to as “lost volume”).

The LD model simulates the advection and dispersion of treated effluent discharged to the Sacramento River at Freeport. The longitudinal dispersion coefficient is an important model parameter. This coefficient, which characterizes longitudinal mixing within the river, is a function of the non-uniformity of the river velocity over the river’s depth, and hence it varies over a specified range. Because this dispersion coefficient has not been measured directly at

[1] These models are described in more detail in Section 5.3.1 (i.e., Model Description and Assumptions) of the Antidegradation Analysis.

[2] The advective distance is the average cumulative distance traveled upstream of the SRWTP outfall by a parcel of water located at the diffuser at the start of a reverse flow event.

Freeport, a sensitivity analysis was conducted to evaluate the effect of low, moderate, and high values of this parameter on model results.

Earlier work by Flow Science, Inc. (FSI) found that “advective distance” was the best indicator of the presence of treated effluent upstream of the SRWTP diffuser during reverse flow events. The advective distance can be calculated directly from velocity measurements made by instrumentation in the Sacramento River at the Freeport Bridge. Note that the method of calculating the advective distance (i.e., multiplying measured velocity by the time elapsed) does not take dispersion of effluent into account; however, it is a practical parameter for tracking the presence of effluent upstream, since it can be computed in real time. Therefore, the advective distance was used as the key parameter in simulating operating rules that could be used by FRWA to avoid diversions of Sacramento River water containing treated effluent.

MODELING RESULTS AND PROPOSED OPERATIONAL PLAN

The model simulations demonstrated several important outcomes as follows: (1) Both volume of SRWTP effluent diverted to the SRWTP’s emergency storage basins (ESBs) and maximum advective distance are virtually independent of variations in critical concentration of effluent and ranges of the longitudinal dispersion coefficient; (2) A slight change in river flow was observed as a result of FRWA pumping; however, volume of SRWTP effluent in the plant’s ESBs and maximum advective distance were only slightly affected. In fact, the maximum intake diversion flow rate of 286 cfs is only about 5% of the minimum daily average river flow rate detected in both Periods 1 and 2 (i.e., May 25 – June 8, 1977 and April 29 – May 12, 1977); (3) A high dispersion coefficient results in the largest loss of FRWA diversion volume, since it causes effluent to spread upstream more rapidly and to reach the FRWA intake more quickly, thereby increasing the time of FRWA pumping curtailment; and (4) A low dispersion coefficient results in smaller lost volume, since effluent does not disperse as quickly as it does for cases with higher dispersion coefficient values, thereby resulting in a shorter time of FRWA pumping curtailment.

Based on the results of this evaluation, SRCSD and FRWA voluntarily worked together to develop a plan of operations that would stop pumping at the FRWA intake when treated effluent is present above a concentration of 0.1 % (corresponding to a dilution of 1000:1) at the FRWA intake. This plan is intended to eliminate diversion of diluted SRWTP effluent into the FRWA intake during reverse flow events. In 2006, a Coordinated Operations Agreement between the SRCSD and FRWA was adopted describing the communications and operations of the facilities by the two agencies. According to the agreement, FRWA will cease diverting at the FRWA intake when the advective upstream distance traveled by the river reaches 0.9 miles upstream of the SRWTP diffuser. When the river begins flowing in the downstream direction again and the calculated advective distance is 0.7 miles or less upstream of SRWTP discharge, FRWA may resume diverting at the FRWA intake.

The voluntary operations plan is conservative in that a pumping regime that follows the rule will result in more lost diversion volume than would a regime that followed a rule that could be customized to the size of individual reverse flow events. Since the characteristics of reverse flow events cannot be predicted accurately in advance without detailed modeling, the operations plan represents the best practical approach to FRWA pump operations. This plan is simple to implement, uses real-time data, and is conservative, thereby providing an operational safety factor for the FRWA diversion.

In late 2008 and early 2009, low river flow conditions resulted in several reverse flow events. Reverse flow conditions observed between October 2008 and February 2009 were used to evaluate the implementation of the operating rule. River flow, velocity, and time data from SRWTP monitoring instrumentation were used to calculate the duration of the reverse flow and advective distance. Flow and velocity data were extracted at 10-minute intervals from an acoustic velocity meter. When river flow reverses, flow is negative. When the river begins to flow back in the downstream direction, flow is positive. The period of time from the start of reverse flow until the river again flows downstream is the duration of the reverse flow event. Distance is calculated at each time interval for the duration of the event. Advective distance is a summation of these distances.

Two of the several reverse flow events that occurred between October 2008 and February 2009 were evaluated and the characteristics of these events are shown in **Table** . These events were selected to represent the range of reverse flow events that occurred during this time period because they were associated with either a maximum or minimum calculated advective distance. The minimum reverse flow event occurred on October 22, 2008 when flow moved 0.003 miles upstream for twenty minutes. The maximum reverse flow event occurred on December 12, 2008 when flow travelled a distance of 0.674 miles upstream of the discharge location. The maximum reverse flow event lasted 3.8 hours.

Table 1: Reverse Flow Events.

Event	Maximum (12/12/08)	Minimum (10/22/08)
Duration (min.)	230	20
Average Velocity (ft/s)	0.26	0.02
Average Flow (kcfs)	2.49	0.31
Distance (mi.)	0.67	0.002

As noted above, the operating rule developed by FSI would require FRWA to cease diverting when the advective distance is calculated to be 0.9 miles. Based on the evaluation of 2008-09 reverse flow events, the maximum calculated advective distance was 0.674 miles. Since the calculated advective distance is less than 0.9 miles, the operating rule would not have been triggered during the December 12, 2008, reverse flow event.